Ice supersaturation and its impact on chemistry and climate

A. Gettelman & D. Kinnison,
National Center for Atmospheric Research

Motivation

- TTL RH controls H_2O in Stratosphere
  - Affects Chemistry: Heterogeneous chemistry
    Polar Stratospheric Clouds, Polar Mesospheric Clouds
  - Affects Climate: radiative impact of stratospheric H_2O
- RH affects Clouds & Cloud radiative impacts
  - Radiative impact of contrails (midlats)
  - Aerosol effects on cloud formation: ΔS_{crit}-->ΔClouds
- (Most) Climate models don't have supersaturation

Outline

Describe Observations of S_{ice} from:

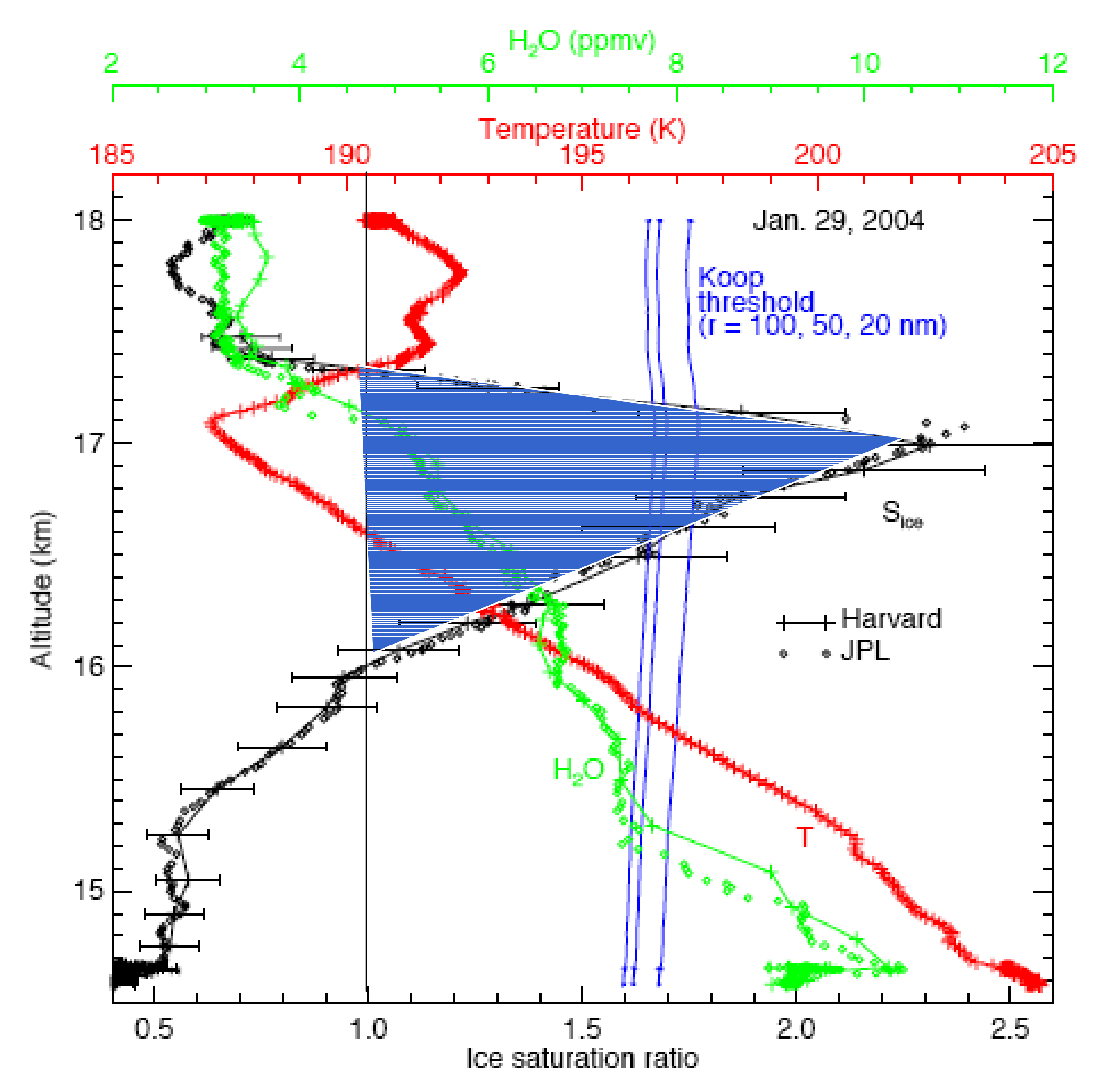
- Balloons
- In-situ aircraft
- Satellites

Present global model solutions with S_{ice}

- Impacts on chemistry and climate

Research Aircraft: Tropics

January, E. Pacific, NASA WB57

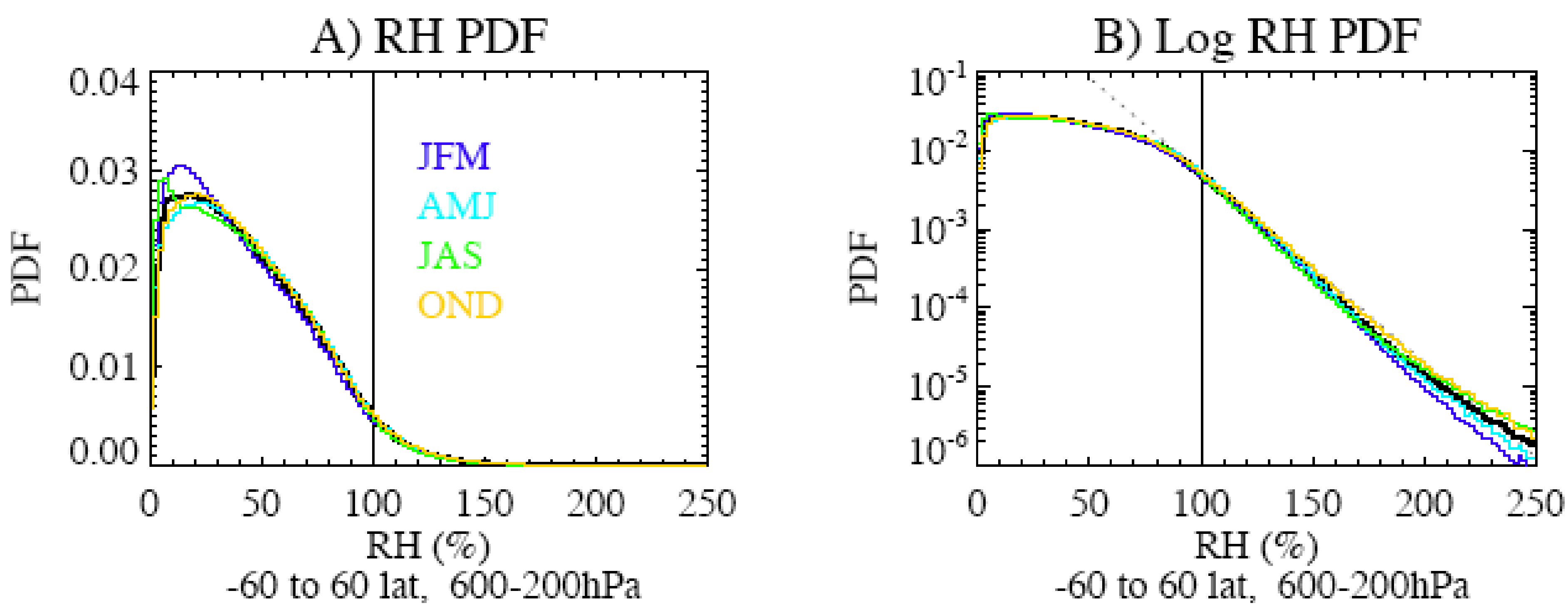


(Jensen et al, 2005)

Size of S_{ice} Regions

- Vertical Extent of S_{ice} regions 560±610m
  - Radiosondes over station in Germany
  - Spichtinger, Meteorologische Zeitschrift, 2003
- Horizontal Extent of S_{ice} regions 150 ± 250km
  - MOZAIC Data
  - Gierens & Spichtinger, Ann. Geophysicae, 2000
- Regions are big enough to see from Satellites
  - S_{ice} seen by UARS-MLS, TOVS
  - Broad vertical weighting difficult to interpret

AIRS RH PDF

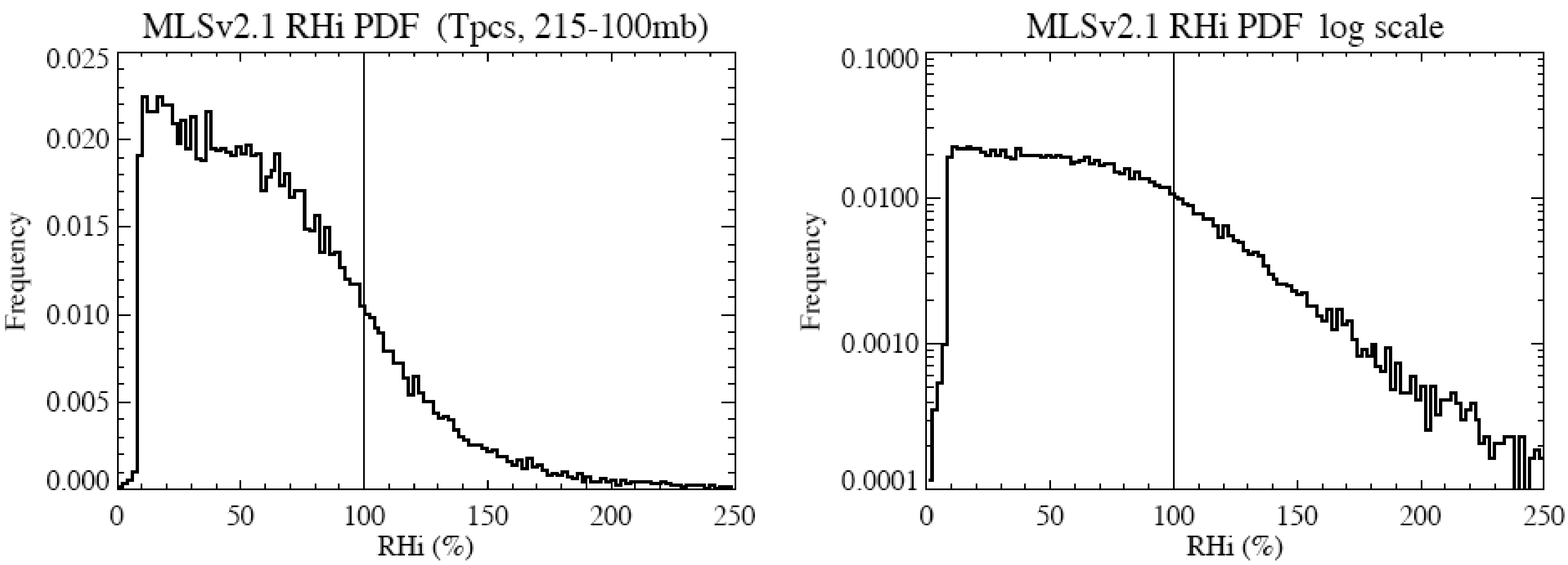


4% supersaturated

AIRS v3 data: Gettelman et al 2006, in press J. Clim

Aura-MLS Observations (PDF)

- MLS v2.1 (higher vertical resolution
  - 8 test days, ‘strict’ quality sort

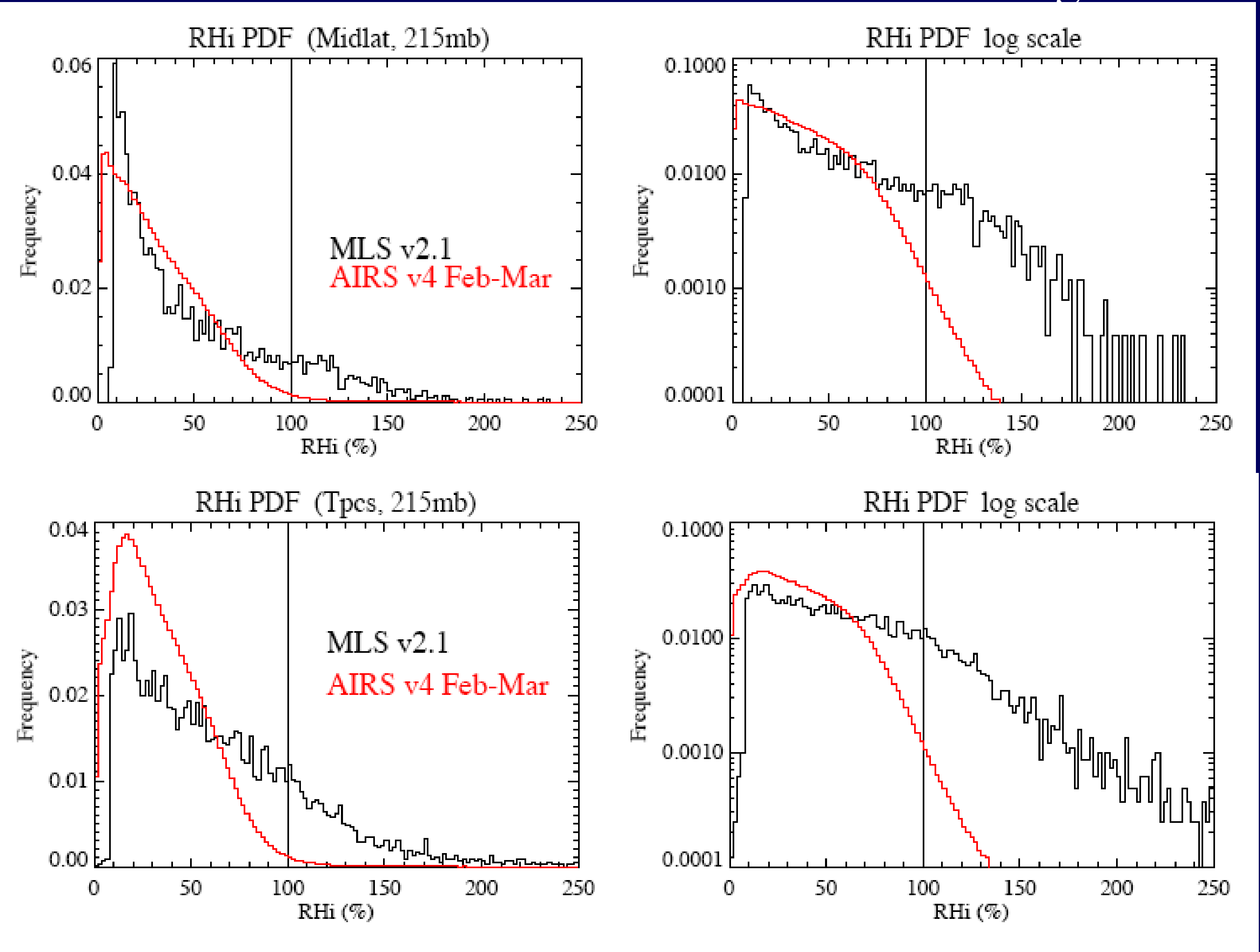


17% observations supersaturated

RH Comparisons w/ AIRS

Linear

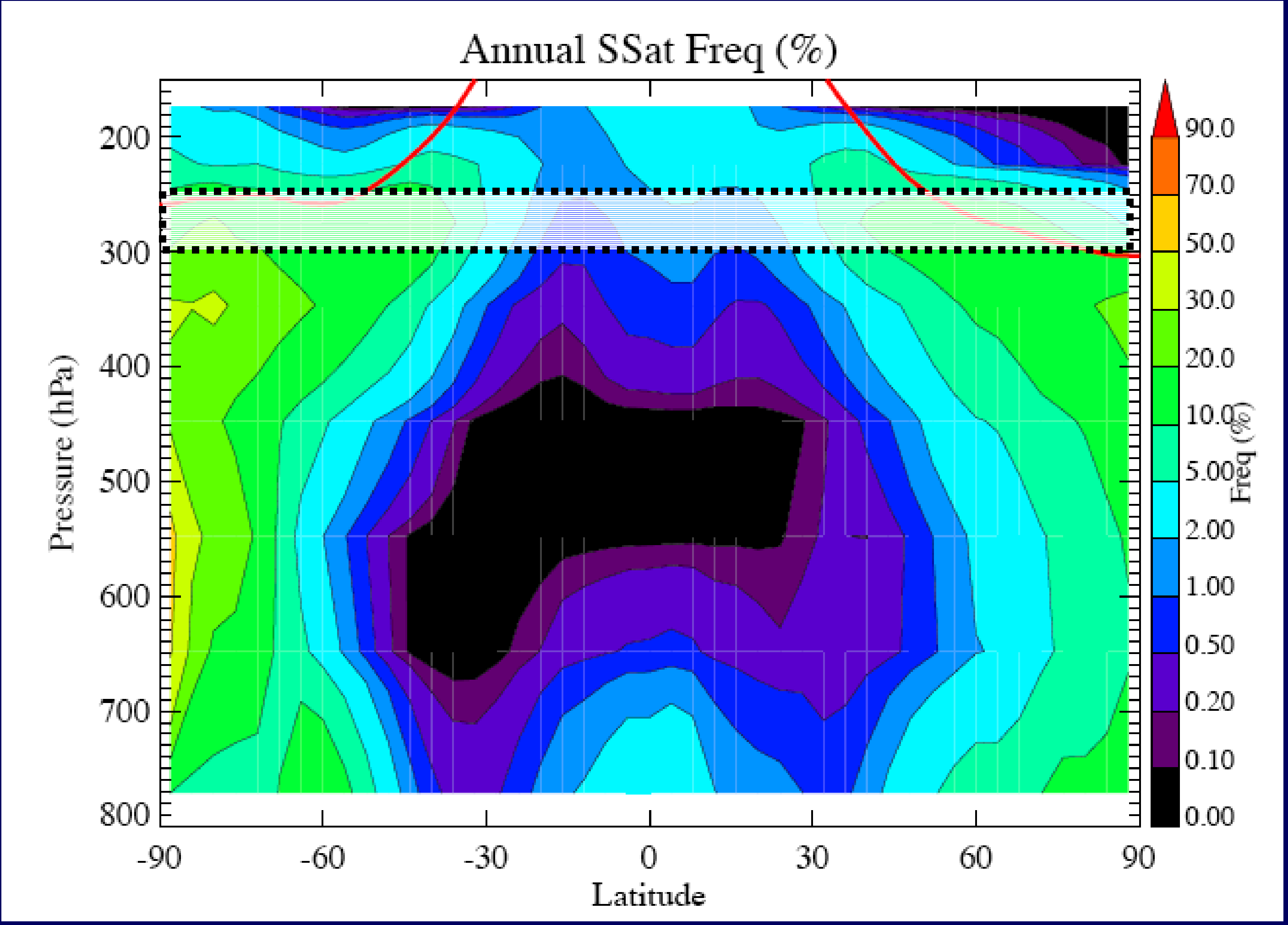
Log



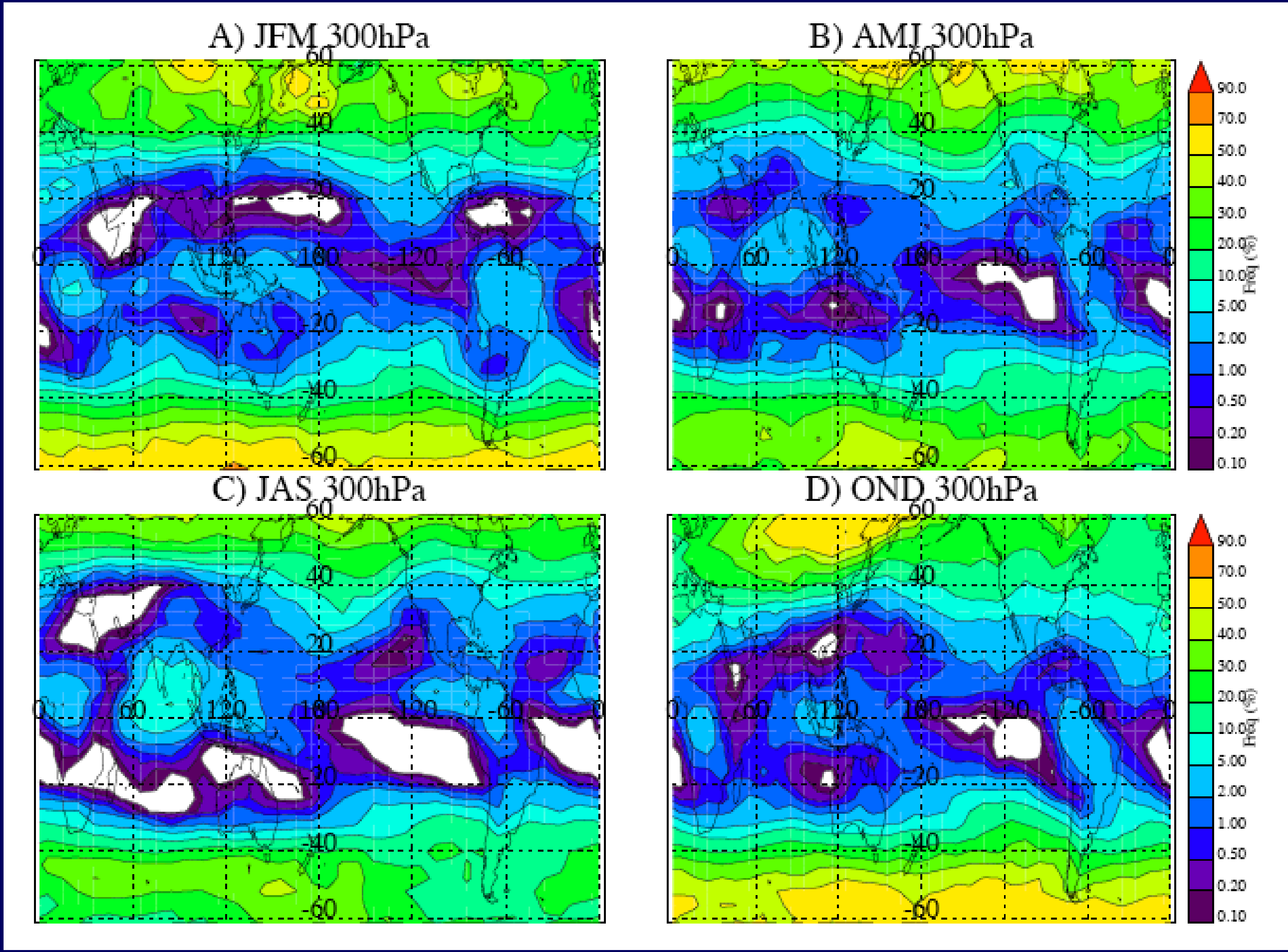
215mb Midlatitudes

215mb Tropics

AIRS Annual S_{ice} Frequency



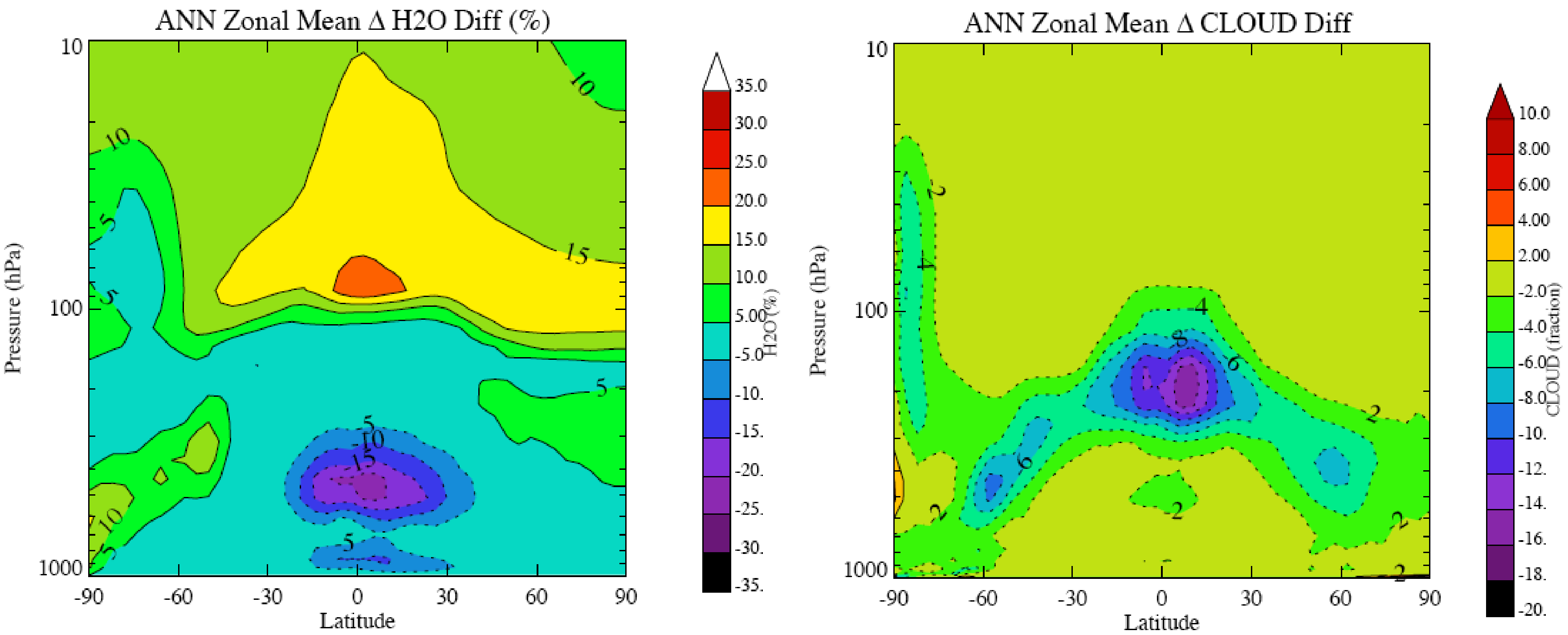
AIRS Frequency S_{ice} 300mb (Trop)



Conclusions: Observations

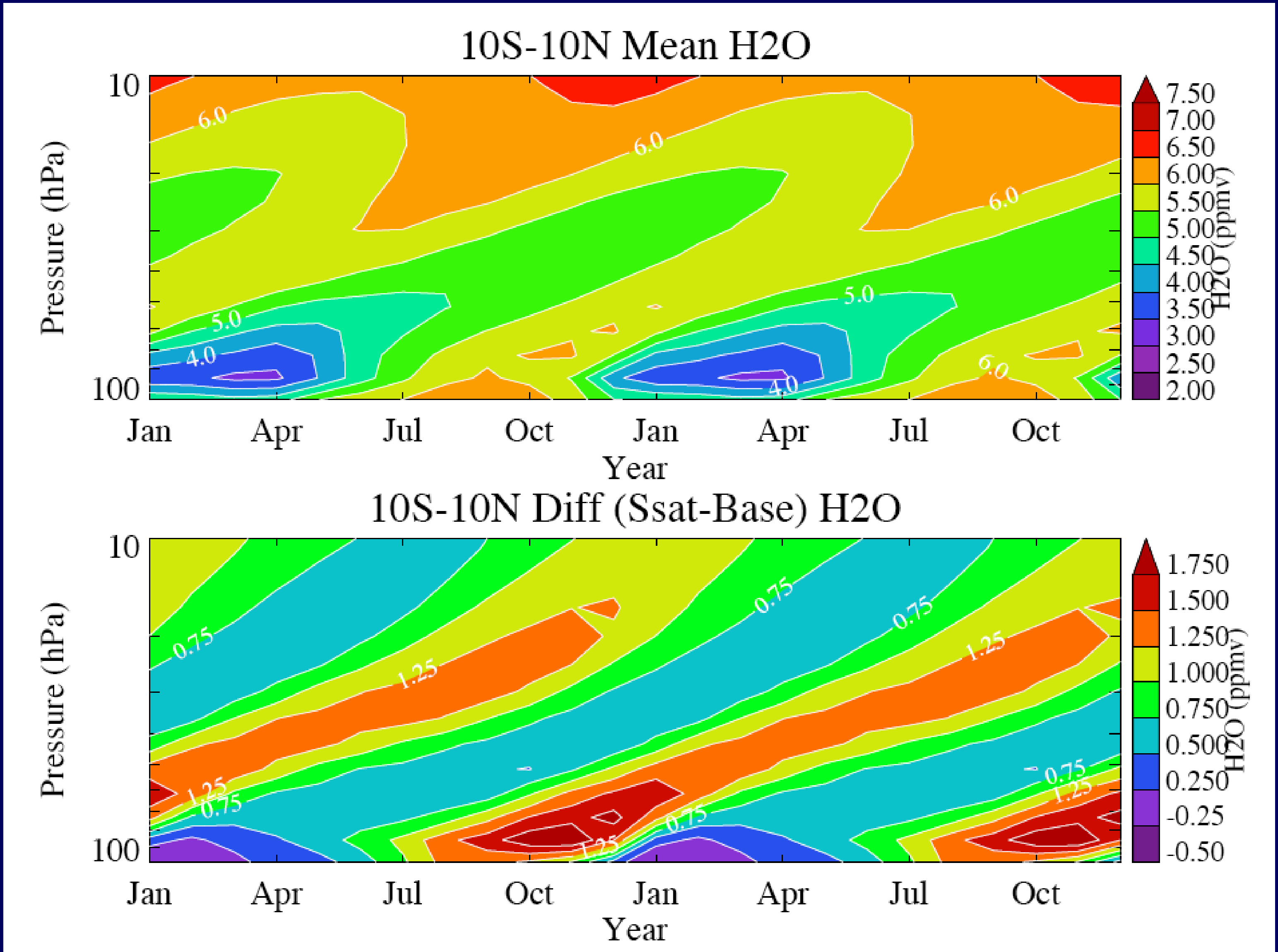
- S_{ice} exists in the atmosphere
  - Difficult to measure
- S_{ice} Regions are large enough to see from satellites
  - Still a highly uncertain measurement
  - Frequency could be off by factor of 2 (AIRS v4)
- S_{ice} Very frequent (20-50% of the time)
  - In UT/LS at a high latitudes
  - In polar regions
  - Around tropical tropopause

Effect of S_{ice} in a GCM

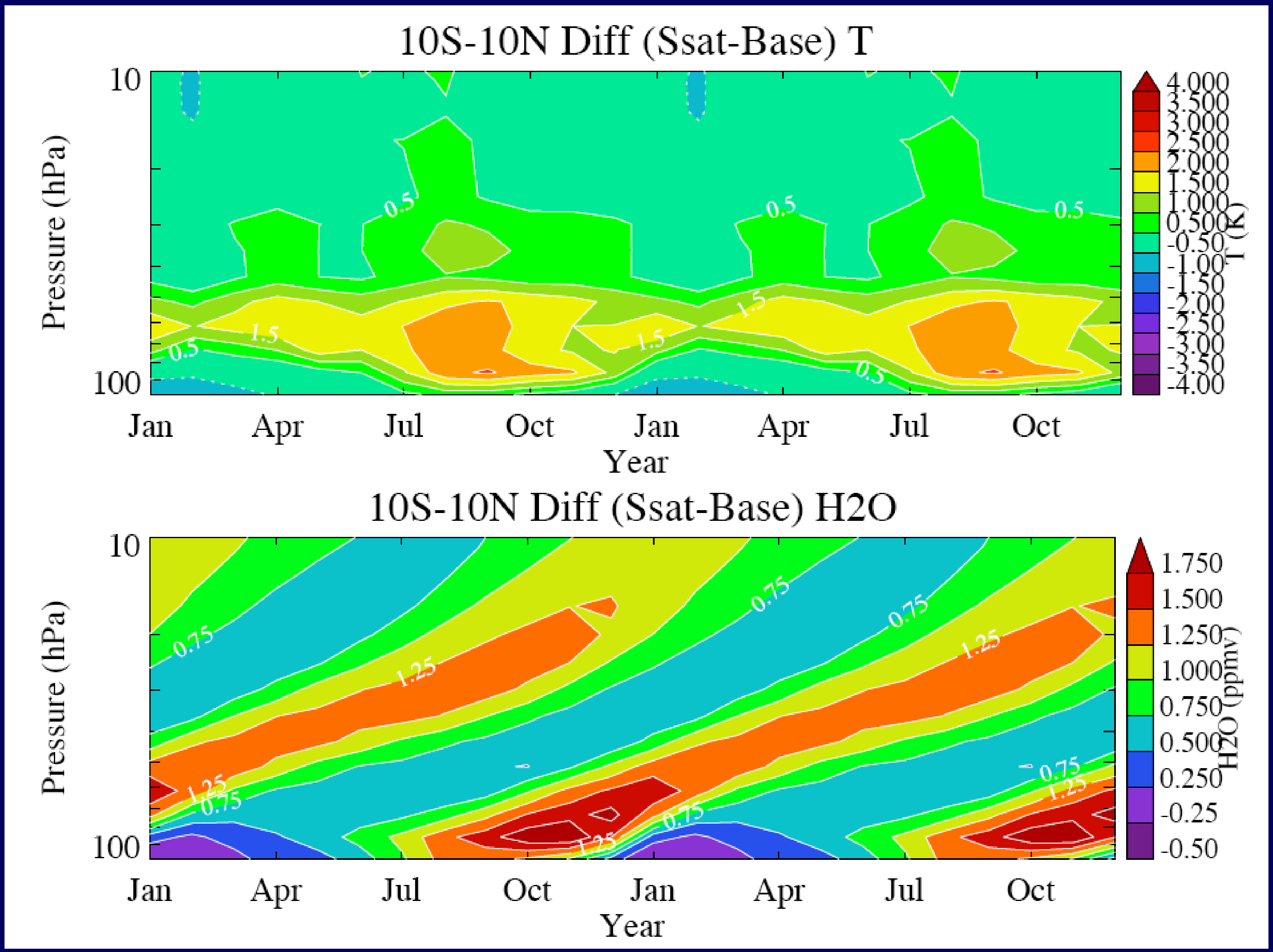


- H_2O goes up and Cloud fraction goes down in supersaturation case
- H_2O increases nearly linearly with S_{ice}
  - Approx 10-20% more in Lower stratosphere, due to Temperature
- Effects Stratospheric Circulation & Chemistry (O_3)

ΔH_2O entering stratosphere

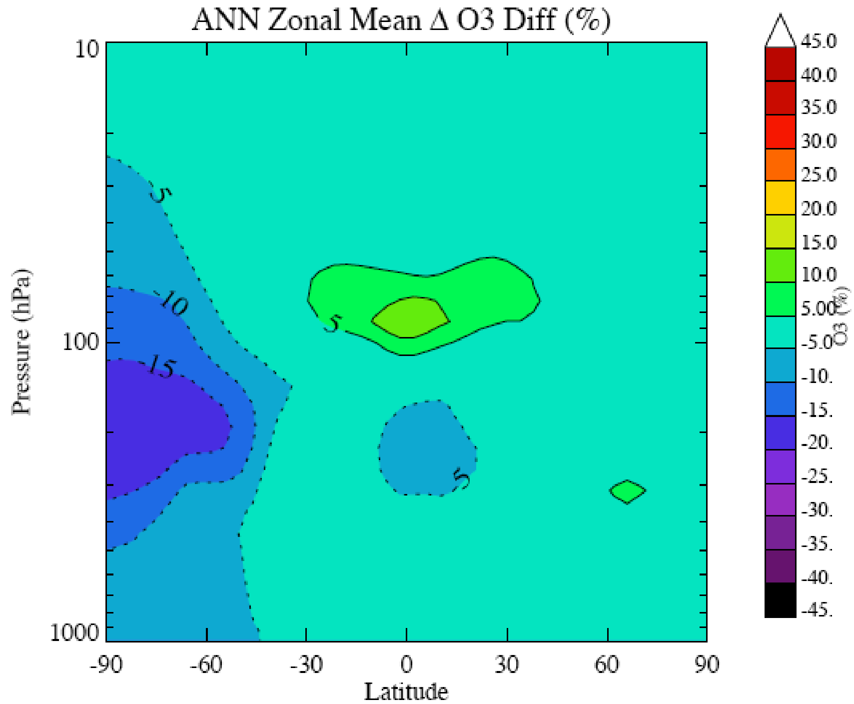


ΔT consistent with ΔH_2O

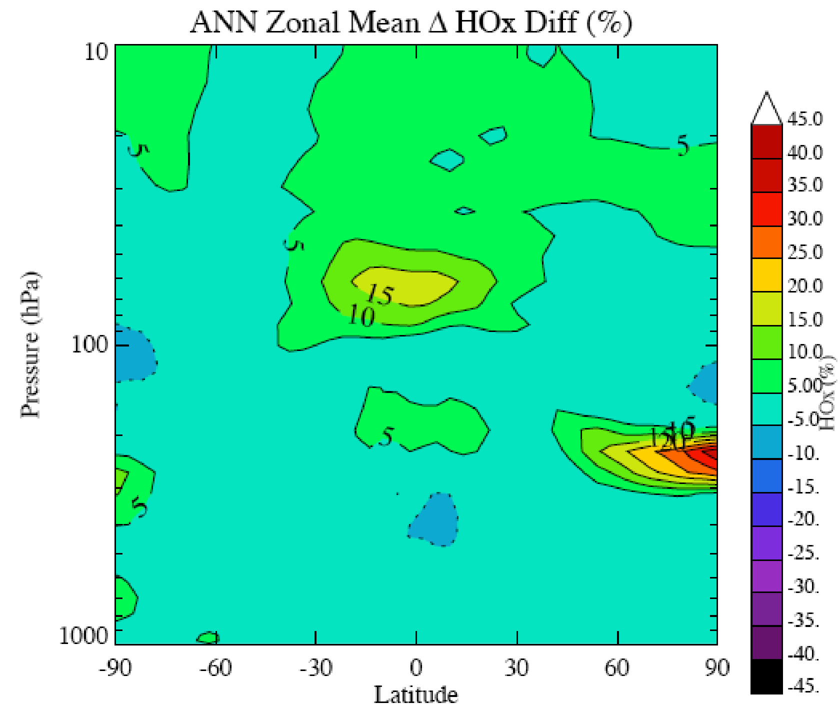


Chemistry Affected

Ozone Change



HO_x Change



O_3 and HO_x both increase above trop
(HO_x = H_2O effect, Why +O_3? Still checking)

Conclusions: Simulations

- Model w/ S_{ice} has less high cloud
  - Reduces cloud radiative forcing
- Stratospheric H_2O response almost linear
  - Larger increases in Jul-Sep due to Tropopause T
- Slowing of stratosphere circulation
  - Seasonal change: consistent with +equatorial Temps
- Small changes in lower strat chemistry (O_3, HO_x)
  - Chemistry may be due to temperature?
- Global radiative impacts:
  - +0.9 Clear (or All) Sky (mostly H_2O)
  - -20% Magnitude of LW & SW Cloud Forcing
  - Reduces Cloud effects (decreases cooling)
  - Enhances H_2O feedbacks (warming)

Overall Conclusions

- Supersaturation common in UT/LS
- Changing condensation (S_{ice}) modifies strat H_2O
- Lower Stratosphere Temperature affected by:
  - Radiation (clouds)
  - Circulation
  - Chemistry? Still checking feedbacks
- Circulation slows
- Reduction of clouds & increase in H_2O = net heating ($\sim 1 Wm^{-2}$), for 20% change in S_{ice}
- Implications: what if aerosols change S_{ice}?